June 7, 1966
2-5443-JKN-007

STAT

To:

cc:

Subject: Acceptance Test Results of the [redacted] 50:1 Zoom System STAT

References: (1) Purchase Order H-671719-9914
(2) Memo 2-5461-JH 0570, "50:1 Projector - Zoom Lens Specification", dated 8-5-66.

SUMMARY

The 50:1 zoom lens system purchased per reference (1) was received on April 20, 1966 and acceptance test was completed on May 27, 1966.

The acceptance test consisted of the following tests:

1. Static Optical Measurements
   - A. Magnification
   - B. Resolution
   - C. Illumination
   - D. Optical Axis Shift
2. Dynamic Optical Measurements

The zoom system requirements are given in the attachment entitled "50:1 Zoom System Specification Limits and Acceptance Test Procedure."

These requirements were generated from the [redacted] specification given in reference (2). The system satisfied all of the requirements of the specification except for the following items: STAT

1. Resolution at 4X magnification is less than the required 20 line pair/mm minimum.

2. The on axis illumination has a deviation greater than the 25% maximum.

3. The optical axis shift varies more than the 0.05 inch maximum over the 50:1 zoom range.

The effect of the above deviations from the specification and the test results are discussed below. Test data is presented in the attachments. The data includes the specification limits, the vendor data and the [redacted] data. STAT

DISCUSSION

The results of the magnification test are indicated in Figure 1. Only one curve is shown since the [redacted] data was identical to the vendor data. This curve relates travel and magnification to the actual magnification of the image on the 24 inch screen. A standard resolution chart was used as the test image. The system was arranged so that at the 4X magnification, the $4\frac{1}{2}$ x $4\frac{1}{2}$ inch film holder outline presented an 18 x 18 inch image on the screen. At 4X magnification there was no vignetting. STAT

The results of the resolution test are given in Figure 2 and Table I. At the low magnification the theoretical limit of the system is 8 line pairs/mm which is less than the specification limit of 20 line pairs/mm. However, since the 4X magnification corresponds to the maximum range of the tracker from the target and since the target is hardly discernable at the initial range, it is considered that the lower resolution is acceptable.

When the illumination test was performed, readings different from the vendor data and also below the specification limit of 3.5 foot-candles were obtained. This data is given in Table II. After thoroughly investigating the test procedure, test technique, and the test equipment it was concluded that something in the system must have shifted during shipment. During these investigative tests the condenser lens servo system became inoperable. It was determined that a Magnetico T-260 incapsulated 60 cps servo amplifier was not functioning properly.

On May 19 it was requested that [redacted] send someone to resolve the problems of the low illumination and the inoperable servo. They complied by having [redacted] on May 23. They brought with them the light meter used during the funotional tests at the [redacted] facilities and a new T-260 servo STAT STAT STAT

amplifier. The new amplifier was installed by [redacted] personnel STAT
STAT under the guidance of [redacted] and the condenser lens servo system was again functional. Then, to verify the low illumination measurements, on-axis illumination was measured with both the [redacted] and STAT
STAT [redacted] light meters. All of the readings were still low and the two meters agreed within 5% of each other. It was agreed that the rest of the illumination measurements would be made with the [redacted] meter. STAT

STAT At this time it was noted that the condenser lens was oscillating or hunting at about 1 cps. [redacted] spent most of the day, May 24, investigating this problem. After coordinating with personnel at
STAT [redacted] he installed a resistor in the servo loop to trim the gain which stopped the hunting.

In an attempt to optimize the complete system, the mechanical stops on the condenser lens were moved out 0.7 inches to give the lens more travel. This in effect increased the illumination at the higher magnification levels by condensing the light on a smaller area of the film. A piece of black film, of the type to be used in tracker evaluations, was subjected to the increased light intensity for a period of one minute to guarantee that the reduced spot size would not damage the film. There is no specification limit on this condition but the time the film is exposed to this more intense light can be limited to a few seconds.

The scale factor of the servo was also trimmed so that the servo was not driving when the lens was at either mechanical stop. When the system was received it was noted that the lens was being driven hard into both stops and that this may have been the cause of the amplifier failure.

The on-axis illumination was again measured and the position of the
STAT arc was varied by [redacted] until an optimum location was found. The complete illumination test was rerun and the results are given in table III and Figures 3 through 5. As may be seen, all values are well above the 3.5 foot-candle minimum. These measurements were made with 2400 watts on the Xenon bulb, the same condition that was in
STAT existence when [redacted] made their measurements.

The only discrepancy in the illumination test occurs on-axis at the 4X magnification. The deviation in illumination level between the 4X and 7.3X magnification is 30% whereas the specification limit is 25% for on-axis deviation. Since this deviation is a continuous function (i.e. not an abrupt change in illumination) and since the change in range involved represents nearly half of the initial range, it is considered that the 30% deviation is acceptable.

The Optical Axis Shift was measured and found to be 0.24 inches. The specification limit is 0.05 inches maximum. The value obtained by the vendor was 0.23 inches. The variation of the shift as a function of magnification was obtained so that its effect on tracker evaluation could be analyzed. This is shown in Figure 6. To the tracker this shift appears as a tracking error. The angle or angle rate corresponding to the shift is proportional to the vehicle acceleration command. If it is determined that the rate of change of the shift is significant

for any particular vehicle simulation, it can be compensated for in the computer program.

STAT The two [redacted] engineers left on May 25. Prior to their departure all of the test discrepancies were discussed. The resolution test was rerun at the higher illumination levels to verify the initial readings.

The Dynamic Optical test indicated the force required to drive the zoom assembly was 23.25 lbs. compared to 24 lbs. measured by the vendor. The specification required 26 lbs. or less.

STAT

[redacted]

Attachments

50:1 ZOOM LENS SPECIFICATION LIMITS AND ACCEPTANCE TEST PROCEDURE

1. Static Optical Measurement

1.1 Format: The format shall be a minimum $4\frac{1}{2}$ x $4\frac{1}{2}$ inch.

Test: Project the $4\frac{1}{2}$ x $4\frac{1}{2}$ inch film holder outline. Note that at 4x it is not vignetted.

1.2 Magnification: The magnification shall be variable through a range of 50:1; end points shall be nominally 4x and 200x.

Test: Project the resolution chart of known scale value. At each end of the zoom range, measure the image at the screen. Calculate the magnification.

1.3 Resolution:

1.3.1 Low Power: At the lowest zoom setting, the axial resolution shall be 20 line pairs per millimeter or better. At the edges of the $4\frac{1}{2}$ inch format the resolution shall be 10 line pairs per millimeter or better.

Test: Set the zoom lens at the lowest magnification. Project the resolution chart at the optical axis. Measure the resolution. The value shall be 20 line pairs/mm or better.

Sequentially observe the resolution chart at each edge of the format. Measure the resolution. The value shall be 10 line pairs/mm or better.

1.3.2 High Power: At the highest magnification setting, the resolution shall be 160 line pairs/mm or better over the entire 24 x 24 inch screen.

Test: Set the zoom at the highest magnification. Project the resolution chart sequentially at the optical axis and at each edge of the screen. Measure the resolution. The value shall be 160 line pairs/mm or better.

1.4 Illumination:

1.4.1 Level: 3.5 foot-candles, minimum shall be projected upon the center of the screen. The value may vary ±25 percent over the entire zoom range.

Test: Locate the light meter probe at the screen plane and on the optical axis. Traverse the zoom range slowly from the lowest to highest magnification. Record the illumination as a function of magnification or shaft position. Calculate the average value. The maximum and minimum values shall deviate no more than 25 percent from the average value. No value shall be less than 3.5 foot-candles.

1.4.2 Uniformity: The illumination at the edge of the screen shall not vary more than 50 percent from the value at the center of the screen.

Test: Locate the Densichron probe sequentially at the center of each edge of the screen plane. Record the illumination. The values shall not vary more than 50 percent from the value at the center of the screen plane for approximately 8 values of magnification.

1.5 Optical Axis Shift:

The shift in optical axis over the 50:1 zoom range shall not exceed 0.05 inch on the screen.

Test: In the film plane, locate the cross hair reticle coincident with the optical axis. Project this reticle and observe its position while traversing the complete zoom range. The reticle image marking the optical axis shall move no more than 0.050 inch.

2. Dynamic Optical Measurements

2.1 Force to Drive Zoom Assembly

The force required to drive the zoom lens and iris control assembly at 2.8 g's shall be 26 pounds, maximum.

Test: Measure the force necessary to overcome the frictional force of the assembly. Weigh the moving elements of the zoom assembly. Calculate the force to accelerate the assembly at 2.8 g's. The sum of the measured and calculated forces shall be 26 pounds or less.

TABLE I

50:1 ZOOM SYSTEM RESOLUTION

STAT [redacted] VS VENDOR

MAGNIFICATION	On Axis		Top Edge		Right Edge		Left Edge		Bottom Edge	
	B	V	B	V	B	V	B	V	B	V
4 X (0")	9.0	9	6.4	8	6.4	8	6.4	8	6.4	8
20 X (2.5")	32	34								
40 X (3.65")	57	62								
80 X (4.8")	91	101								
120 X (5.5")	128	125								
160 X (5.95")	144	144								
200 X (6.3")	161	162	161	162	161	162	161	162	161	162

STAT

2-543-JKN-007
Attachment
Page 3

TABLE II

*50:1 ZOOM SYSTEM ILLUMINATION

STAT [redacted] VS VENDOR

MAGNIFICATION	#On Axis		Top Edge		Right Edge		Left Edge		Bottom Edge	
	B	V	B	V	B	V	B	V	B	V
4 X (L)	4.5	6.1	4.2	6.6	4.0	6.3	4.4	6.5	4.2	6.0
7.3 X (1")	3.4	4.4	3.6	3.6	2.6	4.1	2.9	4.9	3.1	5.1
13.8 X (2")	3.4	4.9	3.4	3.7	2.4	3.5	2.3	5.0	3.3	5.9
25.5 X (3")	3.4	4.9	3.0	3.5	2.4	3.4	2.3	4.9	3.3	5.9
47.5 X (4")	3.0	4.4	2.3	3.4	2.4	3.2	2.2	4.2	3.0	5.4
88 X (5")	2.9	4.4	3.8	4.4	2.6	3.8	2.4	4.1	2.9	4.7
162 X (6")	2.6	4.0	2.4	4.3	2.7	4.2	2.4	4.0	2.9	3.1
200 X (6.3")	2.7	4.2	2.4	4.3	2.7	4.3	2.5	4.2	2.9	3.9

STAT [redacted] readings made with 2100 watts to bulb. Vendor readings made with 2400 watts to bulb. Additional 300 watts would add approximately 10% to

STAT [redacted] readings.

#All readings in foot-candles.

2-5443-JKN-007
At [redacted]ment
Page 4

STAT

STAT

TABLE III

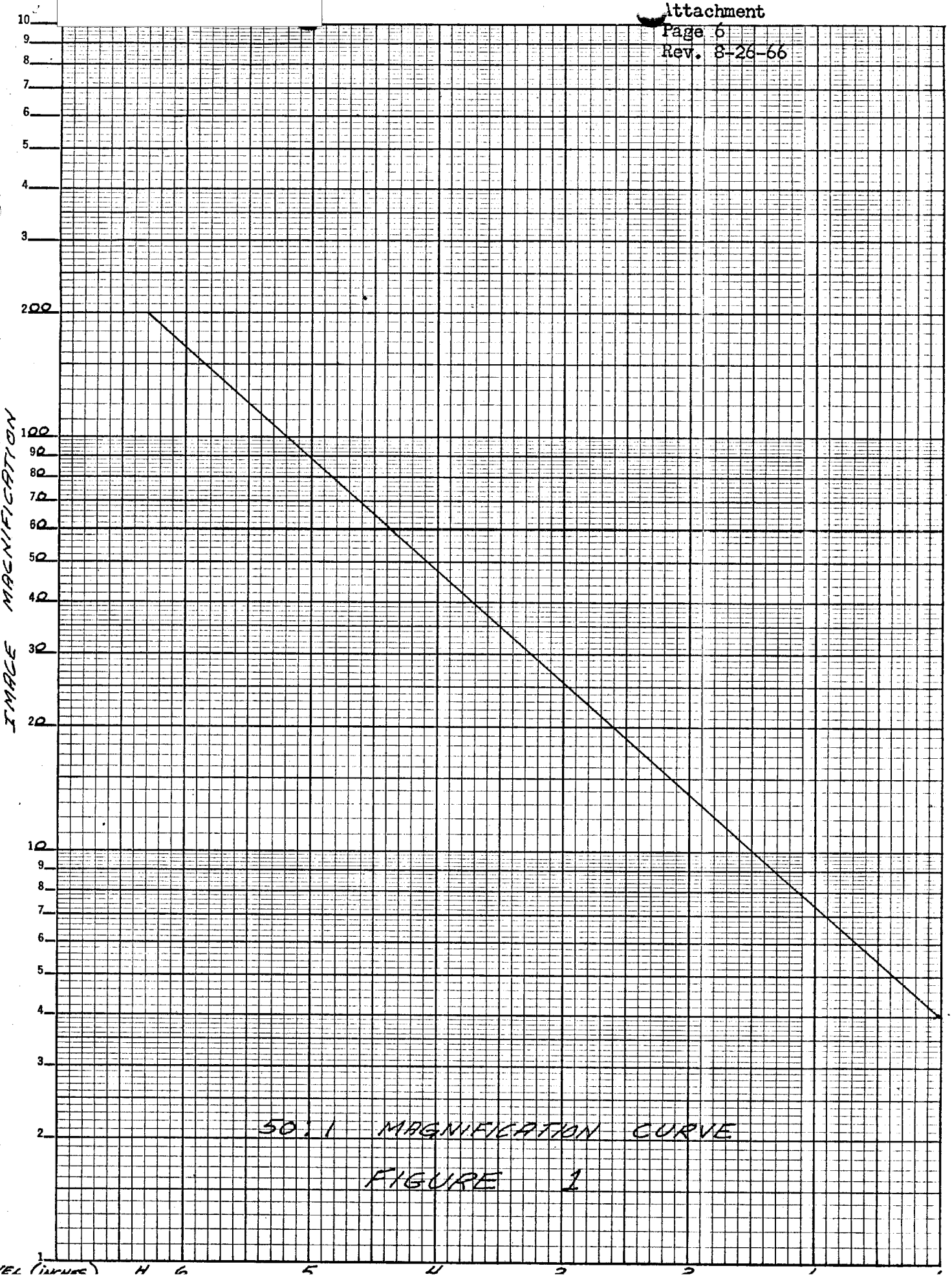
50:1 ZOOM SYSTEM ILLUMINATION

[redacted] VS VENDOR

MAGNIFICATION	#On Axis		Top Edge		Right Edge		Left Edge		Bottom Edge	
	B	V	B	V	B	V	B	V	B	V
4 X (L)	6.9	6.1	5.75	6.6	6.9	6.3	6.3	6.5	6.9	6.0
7.3 X (1")	5.15	4.4	5.1	3.6	4.7	4.1	4.7	4.9	4.8	5.1
13.8 X (2")	5.65	4.9	6.4	3.7	4.25	3.5	4.35	5.0	5.2	5.9
25.5 X (3")	5.65	4.9	5.4	3.5	4.2	3.4	4.15	4.9	5.15	5.9
47.5 X (4")	4.75	4.4	4.15	3.4	4.05	3.2	3.95	4.2	4.7	5.4
88 X (5")	4.2	4.4	3.7	4.4	4.05	3.8	3.85	4.1	4.25	4.7
162 X (6")	4.75	4.0	4.5	4.3	4.75	4.2	4.4	4.0	4.7	3.1
200 X (6.3")	5.4	4.2	5.9	4.3	5.5	4.3	4.9	4.2	5.2	3.9

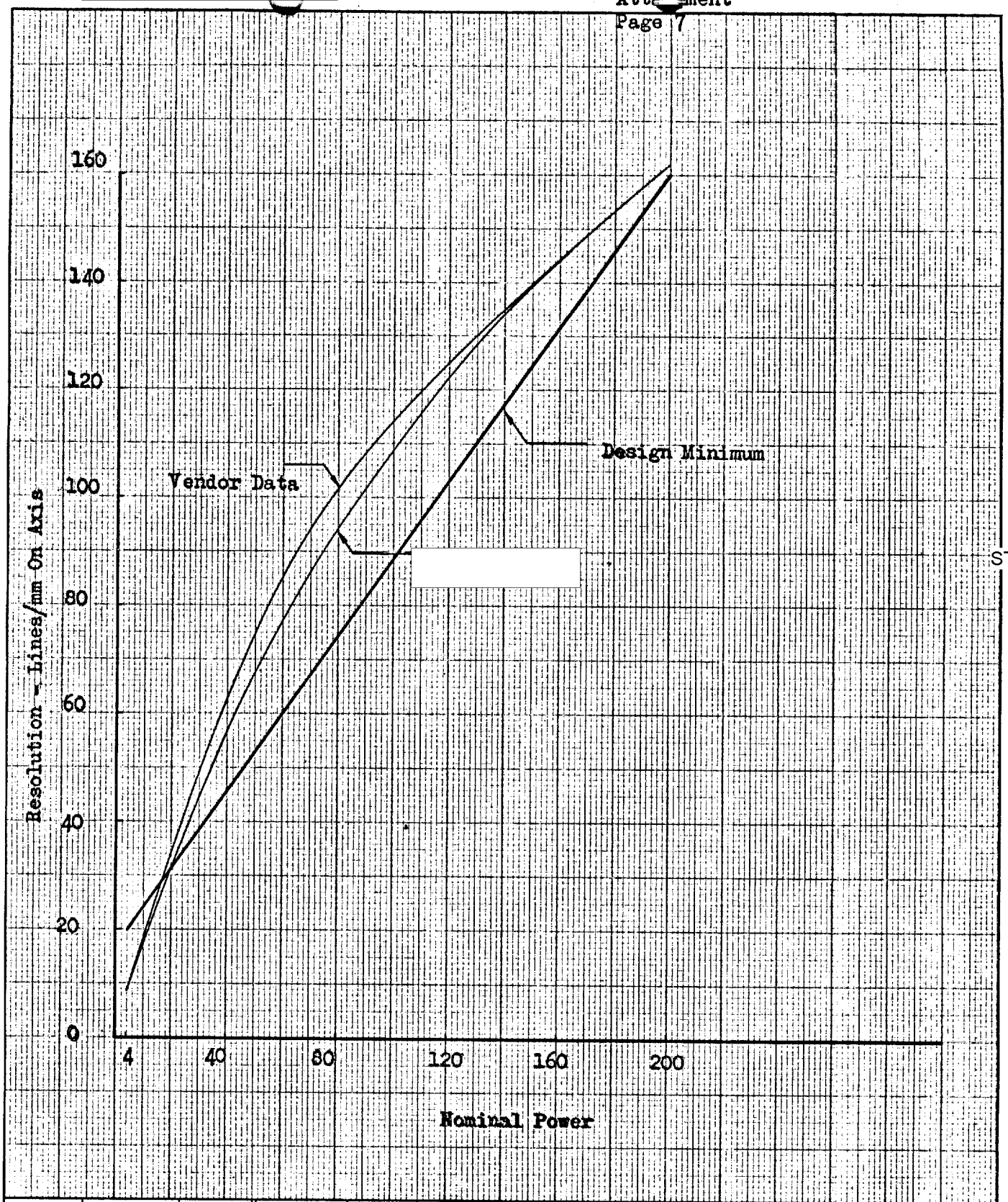
#All readings in foot-candles with 2400 watts to bulb

2-5[redacted]-JKN-007
Attachment
Page 5



50:1 MAGNIFICATION CURVE

FIGURE 1



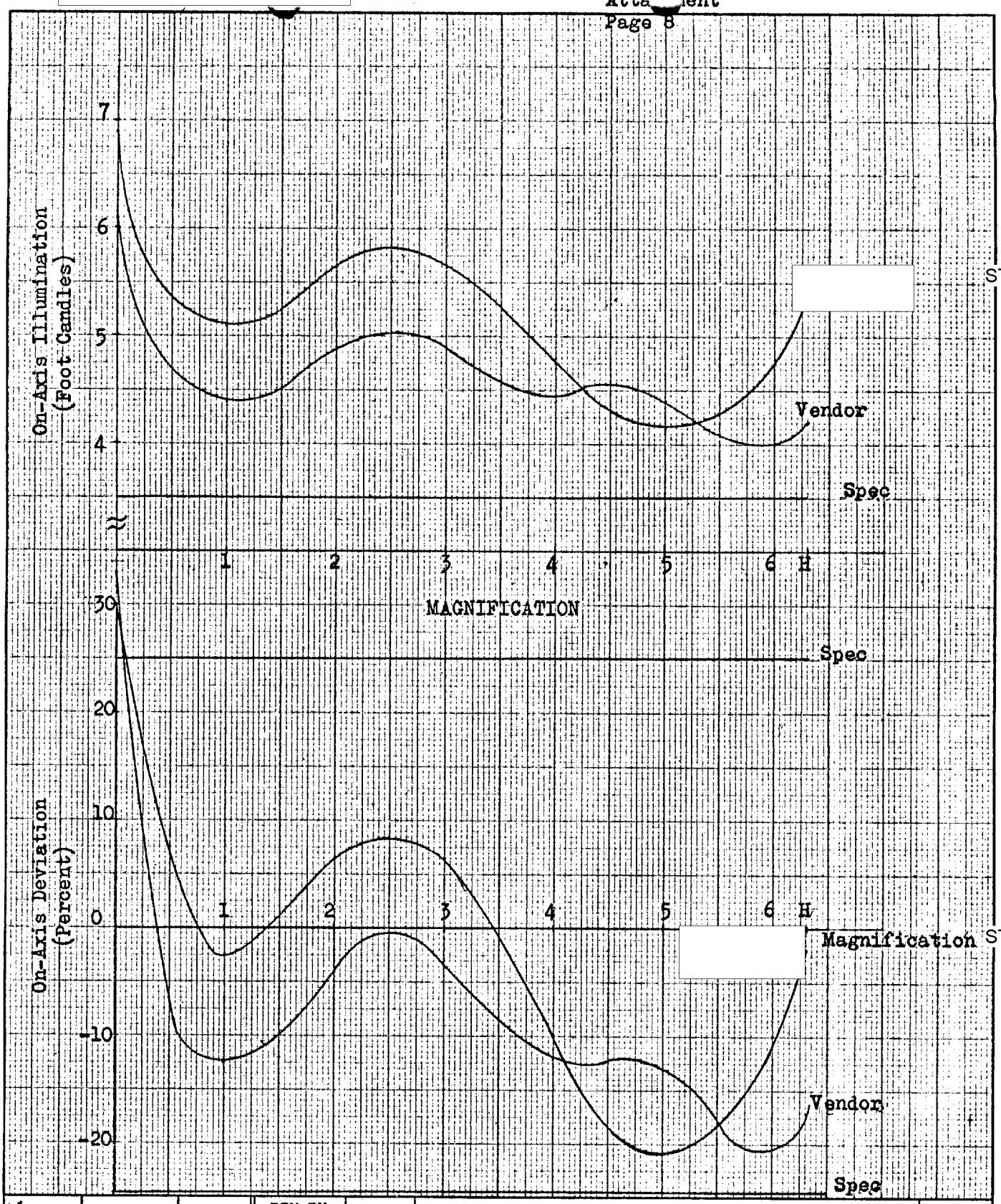
STAT

	INITIALS	DATE	REV BY INITIAL	DATE	TITLE	MODEL
CALC					50:1 ZOOM SYSTEM RESOLUTION FIGURE 2	
CHECK						
APPD.						
APPD.						

U3 4013 8000 REV. 1/66

REV LTR_____ O. _____

STAT



STAT

STAT

	INITIALS	DATE	REV BY INITIAL	DATE	TITLE	MODEL
CALC	RDT	6/1/66			ON-AXIS ILLUMINATION AND DEVIATION FIGURE 3	
CHECK						
APPD.						
APPD.						

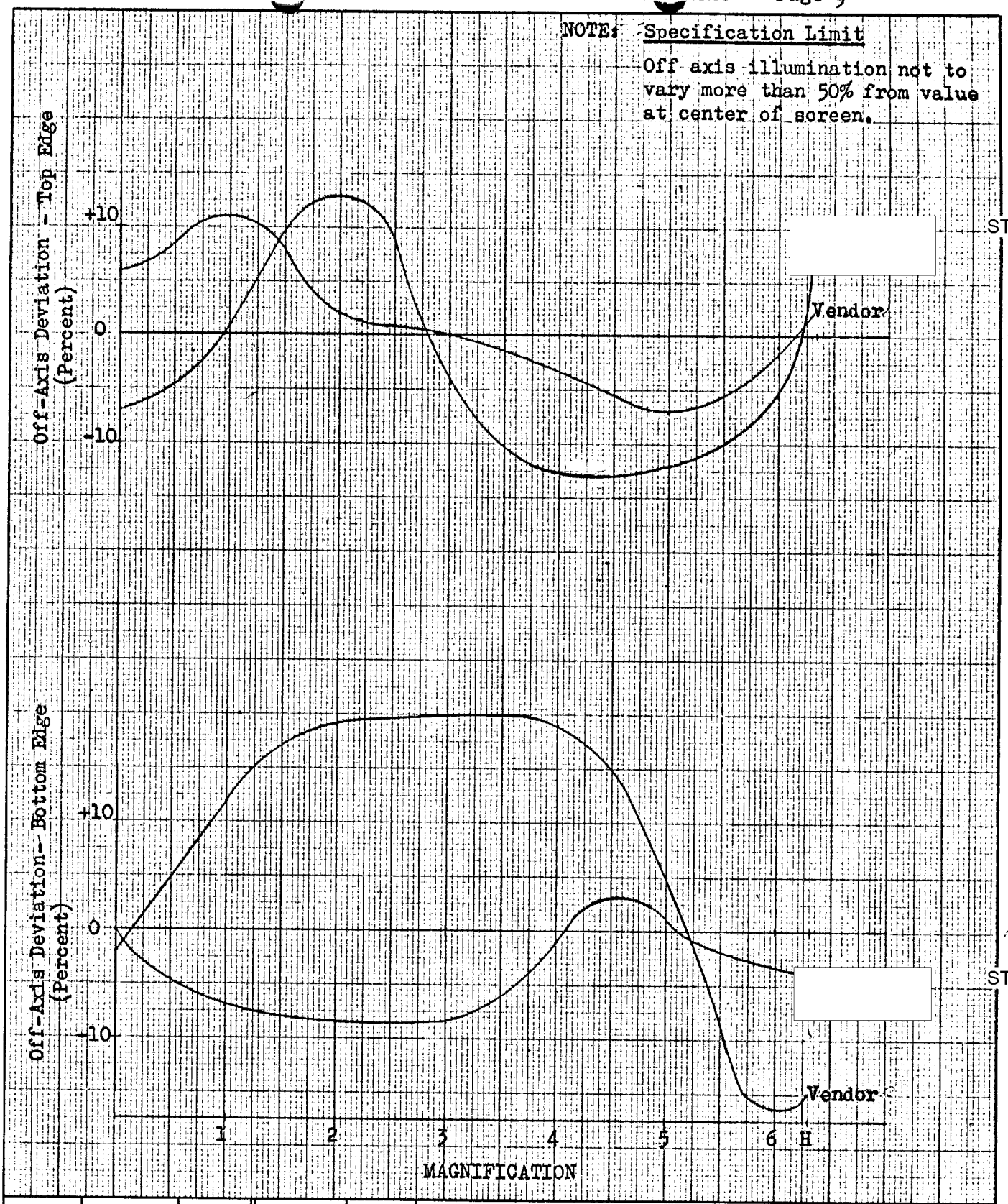
U3 4013 8000 REV. 1/66

STAT

REV LTR_____

NOTE: Specification Limit

Off axis illumination not to vary more than 50% from value at center of screen.



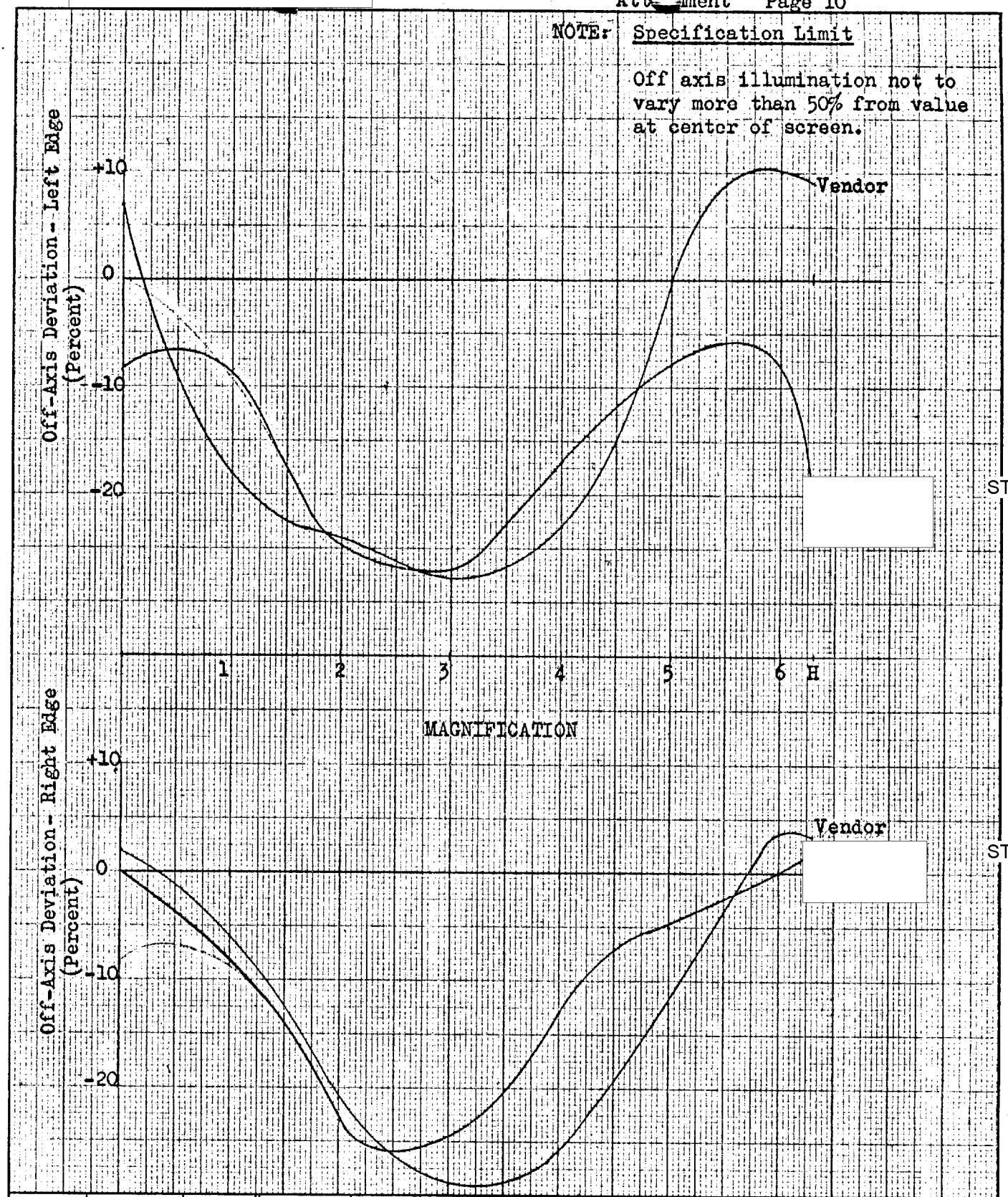
	INITIALS	DATE	REV BY INITIAL	DATE	TITLE	MODEL
CALC	ROT	6/1/66			OFF AXIS DEVIATION (TOP AND BOTTOM EDGES) FIGURE 4	
CHECK						
APPD.						
APPD.						

U3 4013 8000 REV. 1/66

REV LTR_____ STAT

NOTE: Specification Limit

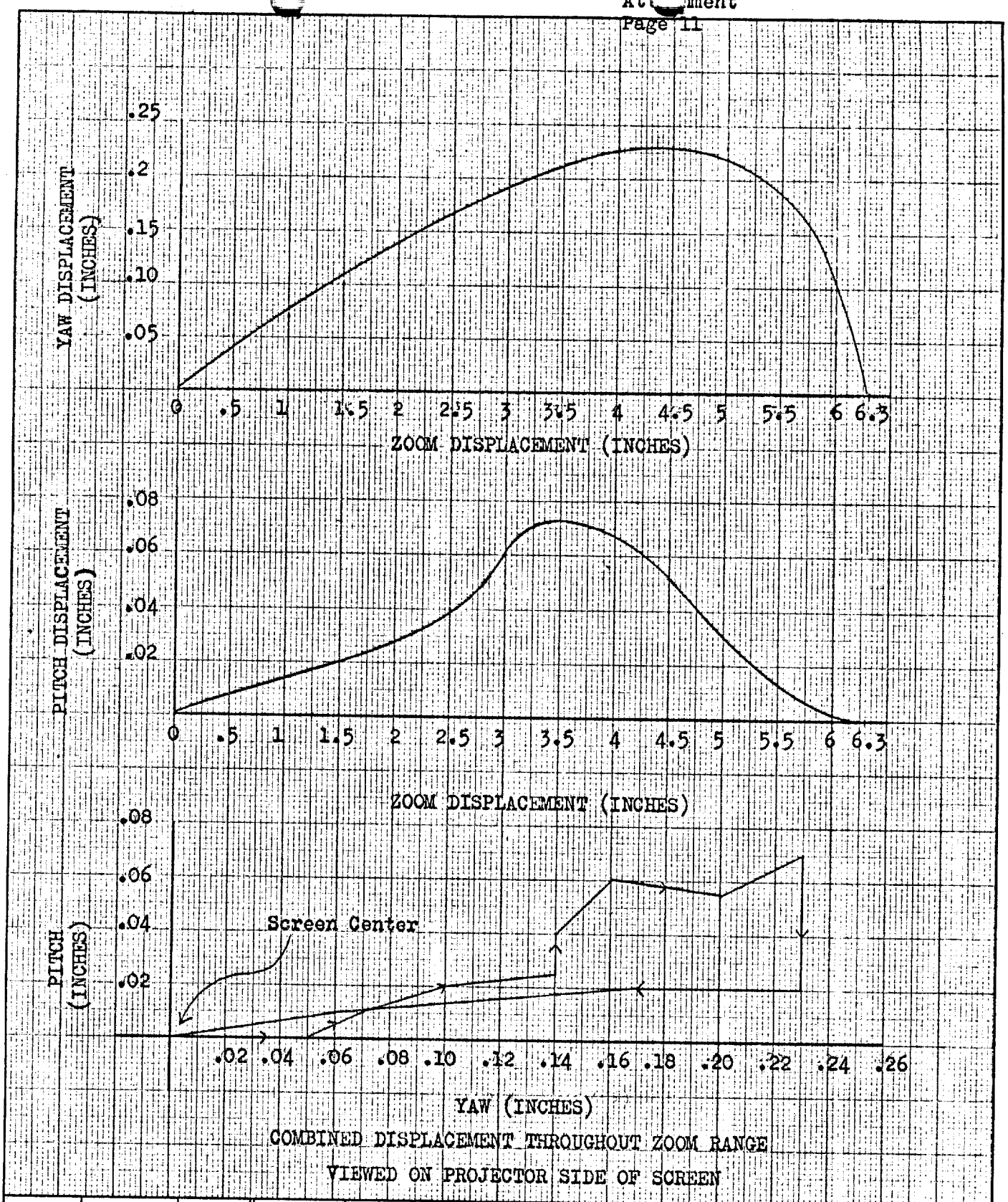
Off axis illumination not to vary more than 50% from value at center of screen.



	INITIALS	DATE	REV BY INITIAL	DATE	TITLE	MODEL
CALC	ROT	6/1/66			OFF AXIS DEVIATION RIGHT AND LEFT EDGES FIGURE 5	
CHECK						
APPD.						
APPD.						

U3 4013 8000 REV. 1/66

REV LTR_____ STAT



	INITIALS	DATE	REV BY INITIAL	DATE	TITLE	MODEL
CALC					OPTICAL AXIS SHIFT Figure 6	
CHECK						
APPD.						
APPD.						

U3 4013 8000 REV. 1/66

REV LTR_____

STAT